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(10) R. N. CORDY*

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*Naval Civil Engineering Laboratory
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This report summarizes the findings of a review of ocean facilities engineering technology in Europe. Principal investigation areas included cable/pipeline burial and trenching, undersea work systems, underwater inspection and non-destructive testing, geotechnical properties of seafloor materials, seawater hydraulic power transmission and diver electrical safety. The investigation which this report summarizes was conducted during May, June, and July 1977. Of particular interest to readers from Naval Laboratories will be the Appendix to this report which describes the Liaison Technologist Program (over)

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under which this investigation was performed. The Appendix ~~also~~ describes the investigation techniques and concepts on the benefits of the Program. For more detailed technical information the reader is encouraged to contact the writer at the Naval Civil Engineering Laboratory, Port Hueneme, CA 93043.

C O N T E N T S

LIAISON TECHNOLOGIST PROGRAM: OCEAN FACILITIES ENGINEERING

LIAISON TECHNOLOGIST PROGRAM:
OCEAN FACILITIES ENGINEERING

INTRODUCTION

In early February 1977, the Naval Civil Engineering Laboratory (CEL) nominated the writer as a Liaison Technologist* to survey the European exploratory development activities in ocean facilities engineering and construction (CEL is the Manager of the Naval Facilities Engineering Command's (NAVFACENGCOM) exploratory development program in this area). Specific topics to be covered included both concrete and cable structures, underwater inspection, anchors and moorings, geotechnical properties of seafloor materials, ocean environmental measurements, diver work and life support systems, remotely controlled work systems, power sources, seafloor excavation, undersea load handling and electromechanical connectors.

Geographically the greatest number of visits were in Scandinavia (Norway and Sweden) and in the United Kingdom (England and Scotland)--13 each. There were four visits in France, three in Italy, two in Germany and one each in Switzerland and Ireland. Of these contacts approximately 24 were commercial organizations, 5 independent and 5 government research and development activities, two universities, and one government R&D program management office. In the large majority of visits most of the time was spent talking with working level engineers.

ORGANIZATIONAL ASPECTS of EUROPEAN TECHNOLOGICAL DEVELOPMENT

There are in Europe, or at least in the U.K., France, and Norway, institutions which could be called quasi-government laboratories. These laboratories are usually established by government agencies but operate as non-profit independent activities. Although not strictly civil servants, the employee status and benefits are not so different. In addition to their research and development orientation, these laboratories also solve field problems and in many cases operate on a commercial basis, e.g., the soil analyses services provided by the Norwegian Geotechnical Institute. The laboratories visited work primarily on commercial projects but in a few cases military tasks are also conducted. The new laboratories are founded

*Appendix A of this report will be of particular interest to Naval research and development activities. This Appendix describes the Liaison Technologist Program under which this ocean facilities engineering survey was conducted. The survey methods are also described and conclusions on the effectiveness of the program are presented.

with financial support from the government (non-military). This includes funds to build and equip offices and laboratories and "guaranteed" funding for the staff for the first few years of operation. For example, one sponsor in Norway is the Royal Norwegian Council for Scientific and Industrial Research. There are similar such Councils in the U.K. and France.

After their establishment these organizations are essentially industrially funded and are encouraged to acquire programs (funds) from industrial sources. However, these laboratories can depend on fixed amounts of government funds each year; the programs supported by these funds are selected by the government Council from proposals forwarded by the Laboratory. The Council is usually comprised of representatives from the major national industries. To keep some reasonable level of objectivity in the selection of programs, recommendations to the Council are often prepared by a review board formed from government staff.

Another common method of funding research projects is that of government/industry fund matching. Thus research on a laboratory project is often funded equally by the government and industry. Often, this research is conducted by the company which is sharing the funding. In most cases the government's contribution is considered a loan which will be paid back out of the future profits of the system being developed.

TECHNICAL SUMMARY

Although there were no major technical surprises, European developments are progressing rapidly in ocean-construction technology and merit continued monitoring and evaluation. One case, the seawater hydraulic motor development at the National Engineering Laboratory in Scotland, may cause CEL to reorient slightly its planned program in this area. There are several other technical areas, of course, where CEL's areas of interest overlap those of various organizations in Europe. The most notable among these are discussed below. A complete list of the organizations contacted and the technology areas discussed is given in Appendix B. For detailed information concerning any portion of this survey, the reader is encouraged to contact the writer at the Naval Civil Engineering Laboratory, Port Hueneme, CA 93043.

1. Cable/pipeline burial and trenching. There is major interest and significant funding being invested in cable/pipeline bural and trenching in Europe. The application for pipeline burial is in support of North Sea oil production operations. The application for the cable burial is for the protection of both communication and power cables from anchor and trawler impacts. Generally, water depths of interest are less than 500 m and protection

distances less than about 200 km. There are as many different techniques as there are systems developers. In total about 11 different burial/trenching schemes were encountered. This is not as bad as it appears, since each application has its own unique set of requirements such as cable/pipe size, length and configuration, soil types and terrain, water depth, support craft, funding and schedule constrains, etc.

Concepts included water jetting, plowing, combination water jetting and plowing, and cutter head type dredging. (The latter is a well-planned, $10 million multi-year program, which is entering final design after successful 6:1 model testing.) Methods of interfacing with the seafloor were just as varied. Wheels of some form are common but tracks and skids are also used. Development of force is accomplished via bootstrapping along a pipeline, interaction of wheels or tracks with the seafloor, or tension cables from the surface. Success has been mixed; several concepts are still under development and have not been used operationally yet.

The information received from these activities, as detailed in the various visit memoranda, will add to the Navy's general knowledge of undersea excavation and seafloor trafficability. Nothing was learned to cause any change to the Navy's existing programs in these technology areas. In fact, most people were favorably impressed with CEL's ideas and approaches on deep ocean cable burial and shallow water trenching and were optimistic for success.

2. Undersea work systems. Other than the cable/pipeline burial work and the wheeled systems discussed below, the underwater work systems being used and developed involve relatively lightweight, low force capability remotely controlled swimming vehicles. Most have been publicized extensively; e.g., the "SNURRE" vehicle operated by Continental Shelf Institute (IKU) in Trondheim, Norway; CONSUB, British Aircraft Corp.; etc. A three-ton vehicle with seven thrusters and three manipulators has been recently fabricated by Saab in Sweden and is being prepared for final testing. The vehicle, "SAAB-SUB," is being built for a major U.S. diving contractor. One of the "SAAB-SUB" manipulators is the new GE force feedback unit (65 lb lift). The other two manipulators are 175-lb lift capability grabbers. Work tools are adapted from standard Stanley (U.S.) hydraulic diver tools. The maximum operating depth is 2,300 ft. Seventy kVA of power is delivered via a quasi-foil shaped cable (to reduce drag) incorporating a Kevlar strength member.

Two bottom work systems with wheels are currently undergoing initial at-sea evaluations. TRAMP, developed by Winn Technology near

Cork, Ireland, is comprised of six independently powered 6-ft diameter tractor-type rubber tires supporting a chassis with a large manipulator arm. This arm can lift 4,000 lb at full horizontal extension and operates within a 25-ft radius working hemisphere. TRAMP has a unique force feedback control system which, in addition to controlling the vehicle, also positions an 8-in.-long scale model of TRAMP located in the control console immediately in front of the operator. Thus the operator actually "sees" in three dimensions the orientation of the vehicle and its manipulator arm.

The second wheeled vehicle, SEABUG, is being developed by UDI of Aberdeen, Scotland, with participation by the National Engineering Laboratory (NEL), Glasgow. It consists of four independently powered wheels, 4-ft diameter and currently about 10-in. width. As with TRAMP, SEABUG can readily change tire types and can add dual wheels to alter ground bearing pressure and tread design. SEABUG is being developed primarily for pipeline inspection services and will be equipped with a complete TV and sonar suite.

Also of interest is a 1½ year, $250,000 feasibility study of a 600-ton off-shore support submarine. This study is being performed by Kockums Shipyard of Malmo, Swden. This manned vehicle would have a submerged endurance of from 2-3 weeks and a payload of about 30 tons.

3. Underwater inspection and non-destructive testing. For certification purposes, North Sea structures must be inspected annually to determine their structural integrity. Inspection of offshore steel structures is primarily for cracks at welded joints and for corrosion. To a great extent, these inspections are performed visually by divers, to a lesser extent by remotely piloted vehicles and rarely by manned submersibles. The typical scenario is for a diver to clean the area to be inspected with powered brushes, high pressure water jets, etc. In many cases a careful visual inspection by fully trained inspector-divers is adequate. In other cases, Det Norske Veritas (DNV is the only firm active in underwater inspection that was contacted) uses a specially developed underwater magnetic particle inspection device to detect cracks. Once a crack is detected, it is removed with a diver-held grinder and rewelded as necessary.

Two new inspection problems are now being investigated by DNV. A recent spot inspection of a pipeline revealed a section where the pipe was suffering from severe internal erosion/corrosion. (The inspection was performed with an acoustic thickness gage.) This section of the pipe was removed and DNV corrosion experts are now studying the sample to identify the damaged mechanism.

This internal erosion/corrosion problem is particularly difficult because of the many hundreds of miles of large diameter pipelines and the obvious difficulty in identifying internal problems.

The second inspection problem is that associated with large underwater concrete structures. The use of concrete gravity structures in the North Sea continues to increase and adequate inspection procedures do not exist. DNV in particular is looking at methods of evaluating the condition of internal reinforcing bars and the possible application of an acoustic technique which can determine density changes in the concrete.

4. <u>Geotechnical properties of seafloor materials</u>. Because of the vast amount of seafloor bearing equipment being used in the North Sea, much interest and effort exists for development of an improved understanding of the long term behavior of seafloor soils. Of particular interest is the prediction of scour and long term settlement of gravity structures, e.g., CONDEEP. Norway in particular has a well developed soil analysis capability centered at the Norwegian Geotechnical Institute in Oslo. On the other hand, there was no evidence anywhere in Europe of any unique coring or sampling capability. Though Comex operates what appeared to be a comprehensive line of coring and sampling equipment, they had nothing that looked particularly innovative.

The NATO SACLANT Research Center is emphasizing shallow water acoustics and as such is beginning investigations of the acoustic properties of seafloor materials. They are also developing refinements to piston corers with which Navy geotechnical engineers are familiar.

There seemed to be no efforts now in Europe associated with the determination of seafloor properties by acoustic techniques. Work completed several years ago by Simrad, Inc., (Oslo, Norway) was reported as being able to classify seafloor surface material into categories such as clay, sand, and gravel. (Simrad was not contacted directly.)

5. <u>Long term use of concrete in the ocean</u>. Several exceptionally large concrete structures are already in place in the North Sea. There is major European concern over the expected life of these structures, especially with respect to corrosion of the reinforcing steel. Programs in both England [Marine Technology Support Unit (MATSU), Harwell], and France [Centre National pour l'Exploitation des Océans (CNEXO), Brest] are investigating this area. Under the technical management of MATSU at Harwell, an extensive well-coordinated program on the use of concrete in the ocean is being pursued (funding probably $2-3 million annually). During

this liaison assignment, relatively little time was spent investigating this subject because CEL researchers are in good contact with their European counterparts.

6. Concrete cutting. At the Battelle Center for Research in Geneva, Switzerland, a new method of drilling holes in, or anchoring to, concrete has been developed. Although most tests have been conducted dry, feasibility for use underwater has been shown. The method, which involves a plasma-jet produced by the oxidation of iron, at first glance would appear complex and impractical for operational use. On the contrary, the equipment seems simple, easily suitable for field use, and the safety precautions are as straightforward as those used in normal gas welding operations. The primary tool is a lance comprised of a hollow iron tube about ½ inch in diameter filled with 8-10 smaller diameter solid iron rods. Oxygen is fed through the interstitial spaces in this tube and combustion is initiated with an electric spark at the tube's end. The lance is then merely inserted into the concrete to be penetrated via a small sand-filled buffer. In concrete a reasonably clean one-inch diameter hole can be produced at a rate of one foot per minute. A modified lance can produce a steel anchor in the concrete in an equally rapid and effective fashion.

7. Seawater hydraulics. About three years ago, NEL began its investigation of seawater hydraulic tools for divers with funding from the Admiralty Experimental Diving Unit (AEDU), Portsmouth, England. AEDU was interested in seawater tools to eliminate potential fire problems when oil hydraulic tools are used in oxygen rich hyperbaric chambers.

Because NEL had previously developed a successful oil-operated ball-piston motor, they started their seawater program with that motor concept. (The oil motor is now manufactured by Rexroth-Carron of Kirkcaldy, Fife, Scotland.) Without any major concept development phase, a slightly modified Carron motor was built from non-corrosion resistant materials in 1975 and tested with good results. The motor operated on about 1,500 psi and produced approximately 5 hp at 1,000 rpm. A second motor was fabricated from corrosion-resistant alloys and testing is scheduled to begin in August 1977.

8. Diver thermal protection. Nearly all of the North Sea diving requires auxiliary heating for the divers. This includes diving operations conducted from bells and lockout diving from submersibles. The primary method is that of providing hot water to a free-flooded diving suit. (Tubing suits are not used and the heated water is not recirculated.) This system is satisfactory for normal operation from a bell. In the case of an accidental cut in the umbilical, the water is heated electrically from on-board batteries. This opn-circuit system is quite inefficient, typically

4-5 kW being required for each diver. Thus adequate battery supplies for emergency operation are quite heavy. Submersible lockout operations are increasing in the North Sea area and the heating of divers from the battery-operated submersibles significantly reduces the submersibles' operating time. (They use the same open-circuit system as bell divers.)

In contrast to this approach the Admiralty Experimental Diving Unit is developing electrically heated diving-suit underwear with appropriate power sources and shock-protection circuitry. (Operating voltage is 24 V dc.) The prototype underwear, fitted with a network of resistance heaters appeared flexible and potentially comfortable to wear. AEDU is also investigating using the heat of crystallization of lithium salts as an energy source.

North Sea operators of bells and submersibles expressed considerable interest in the CEL magnesium-seawater heat source and further information exchange in this area is expected.

9. Diver electrical safety. In Europe, electrical power equipment is used extensively underwater in the immediate vicinity of divers. A very common tool is the electro-hydraulic power converter which typically operates at 380-440 vac, 50-60 Hz. This converter is then used to power hydraulic tools operated by divers. These converters are usually equipped with relatively fast circuit breakers (10 ms to 30 ms is typical) and sometimes are equipped with secondary low voltage circuits to monitor power cable insulation resistance. Most of this equipment has been designed with only an intuitive understanding of underwater electrical fields and their interaction with the diver's physiological system. However, to the writer's knowledge, nobody has reported a diving fatality from electrocution, but nearly every diver I met in Europe has experienced severe electrical shock at some period of his diving career. Electrical safety for divers was also the topic of the 24 May 1977 London meeting of the Society of Underwater Technology. Minutes will be available from them at 1 Birdcage Walk, London SW.1.

Considerable interest exists in the U.K. and the Department of Energy is sponsoring research at Electrical Research Associates (ERA), Leatherhead, England. ERA has recently completed an investigation which reviews physiological criteria for protection of divers against electric shock. The draft report is now being reviewed at the Marine Technology Support Unit, Harwell, England.

Work underway now at ERA includes:

a. An investigation of the feasibility of using diver-worn sensors to monitor voltage gradients. These sensors would produce audible warnings to the divers or automatic circuit cutoffs,

b. An assessment of the shock risk to divers resulting from ripple voltages generated by welding sets, and

c. A survey of equipment to limit the open circuit voltage of arc welding sets.

CONCLUSIONS AND RECOMMENDATIONS

Because of the broad spectrum of European activity in ocean technology surveyed, the results of this 11-week investigation cannot be considered comprehensive. Further investigations of a broader nature seeking to identify new technology, especially at the laboratory research level, would be productive. In addition, since this investigation concentrated on commercial organizations, the development efforts at the many European military and other governmental activities need to be assessed.

With the encroachment of offshore oil exploration and production activities into traditional fishing grounds, European progress in cable/pipeline protection is expected to advance rapidly in contrast to U.S. efforts. Thus, this technology warrants close monitoring.

With the rapidly increasing numbers of offshore structures and the inherent aging process, much European research and development effort is being placed in the field of underwater inspection and non-destructive testing. Significant advancements are expected for both steel and concrete structures.

European research and development resources are being applied to the fields of remote controlled undersea work systems, diver work systems, diver thermal protection and geotechnical properties of seafloor materials. All of these European technology areas are worthy of continued regular assessment.

APPENDIX A

Liaison Technologist Program

1. Program Description

Simply stated, the mission of ONR London is to serve all echelons of the U.S. Navy in matters of science and technology in Europe and the Middle East. The objective of ONRL's scientific liaison is to insure that the Navy R&D community is quickly and effectively informed on items of scientific discovery that may have potential military application. This goal is accomplished primarily by face-to-face meetings between highly specialized ONRL professional staff and the leading European scientists. Such dialogue forms the basis for numerous ONRL reports and their monthly periodical, *European Scientific Notes*. *ESN* is distributed to approximately 6,500 U.S. Navy and other government activities and personnel.

With ONRL's relatively small professional staff of approximately twelve scientists and five officers, somewhat of a coverage gap necessarily exists in technology areas at the exploratory development level. To enhance liaison activity in this technology area and to couple the Naval Laboratory/System Command R&D community more directly with European exploratory development activities, ONRL has established a Liaison Technologist Program. In this program, Navy Lab/Syscom scientists and engineers are temporarily assigned to ONRL for periods ranging from two months to one year. In this assignment, in-depth reviews are conducted of specific European exploratory development technologies.

Technologies and personnel are selected by the Lab/Syscom with consultation with ONRL. The selected personnel remain on the rolls of their parent activity but operate under the scientific aegis of ONRL. As such, the Liaison Technologists receive logistic support and are fully integrated into the ONRL operation during the period of their assignment. To encourage participation in the Liaison Technologist Program, ONRL pays for a significant portion of the travel and per diem costs; generally those incurred when traveling away from the London area. All other costs are the responsibility of the participating activity. Approval of the CEL proposed program was received from ONRL in less than one month and the assignment began in London on May 9, 1977. The planned duration of the assignment was 2½ months. It was completed on schedule.

2. Survey Approach

Over the past several years of conducting the NAVFAC Ocean Engineering Program at CEL, a number of European activities actively involved in ocean facilities engineering have been identified. With only a few exceptions, CEL engineers and scientists have had little opportunity to contact their counterparts in Europe personally. The exceptions were a few visits at CEL from European researchers, three or four "exchange" engineers assigned to CEL (from Germany and Norway), and participation at two or three European technical conferences. Thus, the writer went to Europe armed with several "must" visits, pages of detailed technical questions, and requests for detailed briefings in a number of technology areas. Most of these questions related to the current research projects of the NAVFAC/CEL Ocean Facilities Engineering Block Program and the several other R&D programs within the Ocean Engineering Department at CEL.

Most of the discussions with European activities concentrated on these topics. This accomplished what I believe to be the Civil Engineering Laboratory's prime purpose in participating in the Liaison Technologist Program. On the other hand, by taking this approach the broader overview of European ocean engineering technology was less than well covered.

To accomplish this broader scope objective, and still keep the typical interview period within one working day, the detailed technical discussions would have to be much more abbreviated and the discussion pursued on a much broader level, perhaps on the program level. In this fashion, the host's complete scope of activities could be determined and reviewed along with some discussion of near-term and long-range goals. The overview approach would also require contact with a more comprehensive and representative cross-section of industrial firms, private and government research and development laboratories, and universities. Also, it would be important to have good contact with the funding agencies and review committees for both commercial and military RDT&E.

Using the visit list prepared in advance by CEL, ONRL staff made necessary arrangements for the initial contacts. Thus, after just a few orientation days at ONRL, the survey task was begun. Each interview was generally begun with a slide briefing of CEL's ocean engineering program to establish areas of common interest. A tentative agenda was then established for the available time and we proceeded to delve into the detailed technical exchange. This format seemed to be very effective in establishing the necessary rapport which then led to an open information exchange. The key to the success of this approach is the "exchange" of

technical information. In trying to get usable information from the host, most of the barriers are removed once they determine that you're not a competitor, you're not selling anything and you're willing to give them information on your work. In fact, it often required some finesse to orient the discussion to their work rather than CEL's. Subsequent to each visit or significant telephone conversation, a memorandum was prepared with details as appropriate with copies for ONRL files and interested personnel at CEL and other Naval activities.

3. Cooperative International Developments

On several occasions, cooperative research and development efforts in one form or another were discussed. These efforts included performance of contract work for CEL, performance by CEL of work for European activities, various personnel exchange programs and joint development programs. These discussions evolved naturally from discussions in areas of common technical interest rather than actually being promoted by the writer. Although the contacts in this particular Liaison Program were primarily commercial rather than governmental, the writer believes the European response would be overwhelming should the U.S. Navy desire additional cooperative efforts.

One firm, Comex Industries of Marseilles, France, expressed interest in a cooperative program with the U.S. not involving the exchange of funds. The idea here was that an R&D program would be agreed to by the participants, and separate tasks assigned with each activity using its own source of funds. Comex's approach would be to develop a program plan with a U.S. laboratory and then go to the French government for funds for their portion. They thought this could be accomplished quickly (2-3 months), with a good probability of success.

A few activities volunteered interest in having a U.S. expert work with them on a consulting basis, and other firms were interested in a simultaneous exchange program where essentially two professionals would just switch desks. This arrangement could be productive, especially if provision was made to allow time for visits away from the host organization. (CEL has hosted foreign scientists and engineers on several occasions for periods of about one year each.)

4. Conclusion

The results of CEL participation in the Liaison Technologist Program will have significant but not extensive impact on the current ocean facilities engineering research and development work at CEL.

Probably the greatest single benefit of participation in the ONRL Liaison Technologist Program is the establishment of personal contacts in most of the technical fields of interest to CEL and the NAVFAC Ocean Facilities Engineering Program. In the conduct of this program over the next few years, these 50-60 good personal contacts should be helpful in tracking European developments.

There is much to be learned and gained through effective contact with European investigators working at the exploratory and advanced development levels. Regular participation by U.S. Navy Laboratory engineers and scientists at European conferences is considered to be essential. In addition, participation in the ONRL Liaison Technologist Program will allow an extensive evaluation of a specific technology and will produce many good professional contacts which will aid the participating laboratories in keeping abreast of European technology.

SUMMARY OF OCEAN FACILITIES ENGINEERING LIAISON TECHNOLOGY PROGRAM

ORGANIZATION NAME	TYPE OF ORGANIZATION	LOCATION	DATE OF VISIT	PRINCIPAL CONTACT	TECHNOLOGY AREAS DISCUSSED
Admiralty Underwater Weapons Establishment	Military	Portland, England	Phonecon 10 May	Mr. Bill Allen	Cable protection and burial
CxJB	Commercial	London	12 May, 3 June	Mr. David Hughes	Diver heating, water jetting, explosive excavation, cable burial, diver tools, electrical safety, concrete research
Marconi International Marine	Commercial	Chelmsford, England	13 May	Mr. Stan Hunter	Acoustic biofouling prevention, acoustic telemetry
Winn Technology	Commercial	Kilbrittain, Co. Cork, Ireland	17 May	Mr. Russell Winn	Seafloor vehicles (TRAMP), underwater inspection, vibratory plowing, seawater hydraulics, manipulator tools, tool holders, underwater mateable hydraulic couplings
Vickers Oceanics	Commercial	Edinburgh, Scotland	18 May	CDR J. Pardoe, Mr. Dick Tuson	Seafloor vehicles (SEACAT), cable protection, underwater jetting, manipulator and diver tools, manned submersibles
National Engineering Laboratory (NEL)	Independent non-profit	East Kilbride, Scotland	19 May	Mr. C. Greeves, Mr. Ian Marr	Seawater hydraulics, seafloor vehicles (SEABUG), hydropin anchors, towing and mooring forces of large structures, vibratory hydraulic systems
J. W. Automarine	Commercial	Holt, Norfolk, England	23 May	Mr. John Wise	Buoyancy lift bags, gas generation

ORGANIZATION NAME	TYPE OF ORGANIZATION	LOCATION	DATE OF VISIT	PRINCIPAL CONTACT	TECHNOLOGY AREAS DISCUSSED
Underwater Security Consultants (USC)	Insurance Consultants	London	24 May	CDR Anthony Lovell-Smith	High pressure water jetting, explosive excavation
Leafields Engineering	Commercial	Corsham, England	Phonecon 24 May	Mr. Ken Jacomb	Propellant gas generation
Admiralty Experimental Diving Unit	Military	Portsmouth, England	25 May	Mr. Ian Himmens LT G. Buntrock, USN	Diver heating, diver tools, electrohydraulic power sources, electrical safety
Centre d'Etudes Nucleaires	Government Research	Saclay, France	26 May	Mr. Jean Vertut	Seafloor trafficability, manipulators, acoustic telemetry, seafloor soil mechanics, nodule mining
Institut Francais du Petrole	Independent non-profit	Paris	27 May	Mr. Pierre Willm	Seafloor soil mechanics, underwater mateable connectors, acoustics telemetry, motion compensation, anchors
Centre National pour l'Exploitation des Oceans (CNEXO) Brittany Oceanographic Center	Government Research	Brest, France	31 May	Mr. Francis Besse Mr. Jacques Legrand	Ocean current measurement, seafloor soil mechanics, concrete research, seafloor nodule mining, seafloor trafficability
Marine Technology Support Unit (MATSU)	Government Research Management	Harwell, England	2 June	Mr. Robert Rudham	Ocean current measurement, structural fatigue and fracture, wave forces on structures, diver tools, electrical safety for divers, seafloor soil mechanics
Vibro-Einspultechnik	Commercial	Hamburg, Germany	6 June	Mr. Rudolf Harmstorf	Cable and pipeline burial and protection, seafloor vehicles

ORGANIZATION NAME	TYPE OF ORGANIZATION	LOCATION	DATE OF VISIT	PRINCIPAL CONTACT	TECHNOLOGY AREAS DISCUSSED
Dornier Systems	Commercial	Friedrichshafen, Germany	7 June	Dr. Roland Schotter	Ocean current measurement, acoustic biofouling protection, submersible winches, seafloor nodule mining
Battelle Center of Research	Independent non-profit	Geneva, Switzerland	8 June	Mr. Rolf Roggen Dr. Eric Anderson	Plasma cutting and drilling of concrete, concrete attachments, undersea welding
Subsea Oil Services	Commercial	Milan, Italy	9 June	Mr. R. Timmerman Mr. V. Alfierie	Diving systems, deep ocean cable burial
Tecnomare	Commercial	Venice, Italy	10 June	Mr. D. Lalli	Cable/pipeline burial and protection, undersea storage of POL, acoustic telemetry
SACLANT ASW Research Center	Military (NATO)	La Spezia, Italy	13 June	CDR Tom Phelps Mr. Tunchay Akal	Seafloor soil mechanics, shallow water acoustics
Comex Industries	Commercial	Marseilles, France	14-15 June	Mr. Peter Wide Mr. Claude de Vaulx Mr. Jean-Francois Faugere	Diving systems, diver heating, diver tools and power sources, underwater mateable connectors, cable burial and protection, seafloor trafficability, underwater inspection, seafloor soil mechanics, underwater placement of concrete, anchors, water jetting and plowing, gas generation, electrical safety for divers
Continental Shelf Institute (IKU)	Independent non-profit	Trondheim, Norway	20 June	Mr. Rolf Jemme	Remotely controlled vehicles, underwater tools, seafloor soil mechanics, underwater surveying, acoustic telemetry

ORGANIZATION NAME	TYPE OF ORGANIZATION	LOCATION	DATE OF VISIT	PRINCIPAL CONTACT	TECHNOLOGY AREAS DISCUSSED
Elektronikklaboratoriet (ELAB - SINTEF)	Commercial	Trondheim, Norway	20 June	Mr. T. Hollup	Seafloor soil mechanics and coring, remotely controlled seafloor equipment
River and Harbor Laboratory (SINTEF)	Commercial	Trondheim, Norway	21 June	Dr. Alf Torum	Wave forces on structures, cable damage by trawlers and cable protection
Institute of Soil Mechanics and Foundation Engineering (Norwegian Technical University)	Independent non-profit	Trondheim, Norway	21 June	Dr. N. Jambu	Seafloor soil mechanics, anchors
Det Norske Veritas (DNV)	Commercial	Oslo, Norway	22 June	Mr. Rune Sletten	Underwater inspection and non-destructive testing, seafloor soil mechanics
Kvaerner Group (Myrens Verksted & Kvaerner Kulde)	Commercial	Oslo, Norway	22 June	Mr. Tom Grimseth Mr. P. Thingstad	Seafloor vehicles, undersea load handling, diver thermal protection
Norwegian Geotechnical Institute	Independent non-profit	Oslo, Norway	23 June	Mr. F. Myrvoll	Seafloor soil mechanics, cable plowing
Kvaerner-Brug	Commercial	Oslo, Norway	23 June	Mr. O. Biberg	Cables/pipeline burial and protection
Fred Olsen Oceanics	Commercial	Tananger, Norway	24 June	Mr. H. D. Tangen, Mr. S. Ytreland	Submersible operations, manipulator and diver tools, diver thermal protection, salvage and recovery systems
Norwegian Underwater Institute (NUI)	Independent non-profit	Bergen, Norway	24-25 June	Dr. B. Vedeler	Diving systems, hyperbaric systems, diver tools, emergency undersea rescue, diver thermal protection

ORGANIZATION NAME	TYPE OF ORGANIZATION	LOCATION	DATE OF VISIT	PRINCIPAL CONTACT	TECHNOLOGY AREAS DISCUSSED
Kockums Shipyard	Commercial	Malmo, Sweden	27 June	Mr. S. Rahmberg	Rescue vehicles, manned work submarines, underwater mateable connectors, underwater tools, rock coring
Marinkonsult	Commercial	Löddenpinge, Sweden	27 June	Mr. H. Lundberg	Diver tools, underwater hull cleaning, underwater ship repair
Saab-Scania	Commercial	Linköping, Sweden	28 June	Mr. G. Alseby	Remotely controlled vehicles, manipulator tools, tool storage
UDI	Commercial	Aberdeen, Scotland	8-9 July	Mr. John Hay	Seafloor mapping, bottom crawling wheeled vehicles
University College of North Wales	University	Bangor, Wales	11 July	Dr. D. Taylor-Smith	Seafloor soil mechanics
University of Newcastle upon Tyne	University	Newcastle upon Tyne	12 July	Dr. Alan Reece	Seafloor plowing, seafloor soil mechanics, ocean engineering topics in general
CJB Offshore	Commercial	London	1 Aug	Mr. Graham Mead	Anchors, ocean construction
Institute of Oceanographic Sciences (IOS)	Independent, non-profit	Wormley, England	2 Aug	Dr. Brian McCartney, Mr. John Bunting	Current measurement, cable dynamics, ocean construction
ERA	Independent, non-profit	Leatherhead, England	3 Aug	Mr. Michael Bradford, Dr. George Mole	Underwater electrical safety